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TABLE OF CONTENTS

The Influence of Temperature upon the Respiration and Heart Activity of *Thermobia* and *Grylloblatta*. *G. A. Edwards* and *W. L. Nutting* 33

The C. Andresen Hubbard Collection of Fleas of the Pacific Northwest. *J. Bequaert* 44

Notes and Descriptions of Western Chrysopidae. (Neuroptera). *N. Banks* 45

Two New Paussid Beetles from the Panama Canal Zone and the Philippines. *P. J. Darlington, Jr.* 68

A New Species of Limnephilidae from Maine (Trichoptera). *N. Banks* 72

Large Raptorial Birds as Enemies of Cicadas. *Charles T. Brues* . . 74

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PSYCHE

VOL. 57 JUNE, 1950 NO. 2

THE INFLUENCE OF TEMPERATURE UPON THE RESPIRATION AND HEART ACTIVITY OF *THERMOBIA* AND *GRYLLOBLATTA*.[1]

BY

GEORGE A. EDWARDS (Tufts College)

and

WM. L. NUTTING (Harvard University)

A recent survey of the literature concerning the metabolism-temperature response of insects suggested that this large and diverse class makes no metabolic adaptations to fluctuations in environmental temperature. Therefore, it seemed appropriate to investigate several specialized insects to determine if metabolic adaptations are made to particular temperature ranges. The initial experiments included representatives of two primitive orders occupying extremes on the temperature scale. It is hoped that these may serve as limits for future work of similar nature on the insects as a group.

The firebrat, *Thermobia domestica* Packard (Thysanura), was selected as the representative of a hot environment. The firebrat has a well deserved name in that it is found in hot, damp places such as boiler rooms. It has a temperature preferendum of 32° to 44° C, and an optimum of 37.5° C and 60% relative humidity, at which level it completes the life cycle in about three months. It molts and continues to increase in weight throughout the whole life span (Adams, 1933; Sweetman, 1938; Woodland, personal communication).

[1] The work described in this paper was done, in part, under contract between the Medical Division, Chemical Corps, U. S. Army and Tufts College. Under the terms of this contract the Chemical Corps neither restricts nor is responsible for the opinions or conclusions of the authors.

Grylloblatta campodeiformis Walker (Orthoptera) was chosen to represent a cold environment. The grylloblattids generally have been collected in late fall and winter, being found in mountainous areas on hillsides with coarse rock slides, in deep crevices, under stones, or in decaying moss-covered logs and stumps at the margins of glacial bogs. On mild winter days a few have been found crawling on the open snow slopes (Gurney, 1948—extensive bibliography). The nymphal stages are long, in *campodeiformis* occupying five years, with the eggs laid in the sixth year (Ford, 1926). Its food consists chiefly of softbodied insects.

Material and Methods

A culture of *Thermobia* that had been maintained at 37.5° C was obtained from Mr. John Woodland, of Harvard University. They were kept in plastic utility dishes in an incubator at 37.5° C and 25% R.H., fed on wheat flour and dried beef, and watered from a vial and wick.

The grylloblattids were obtained from Dr. J. H. Pepper, of Montana State College. They were kept in plastic dishes at 3° to 5° C in a mixture of moss and leaves and fed on pieces of freshly killed flies and roaches.

The oxygen consumption was determined in volumetric microrespirometers (Scholander, 1942), using "Ascarite" to absorb CO_2 produced, oxygen from "Oxybombs" to fill the reservoirs, and shell vials of appropriate size for animal chambers. Constant temperature at each level was secured by immersing the respirometers in stirred, plastic, water baths, which were immersed in turn in a large, stirred, thermoregulated water bath. The animals were exposed to each temperature for about 1½ hours. At the end of each run the animals were weighed and their sex determined.

For determining the heart rate, each insect was coaxed into a short length of glass tubing, the ends of which were then lightly plugged with cotton. This confinement prevented violent struggling and afforded a clear view of a few cardiac chambers. Of the several available grylloblattids, only two adult females proved suitable for accurate observation of heart activity through intersegmental membranes of the anterior abdominal region. Five adult females and four adult males of *Thermobia* were selected. Each of these specimens was nearly free of scales, while dark material in the crop made

the heart visible through the mesothorax and first abdominal segment.

The tube containing the insect was placed on a plasticine platform in a porcelain crucible which could be closed with a loose-fitting, transparent cover. The temperature of the air in the chamber was taken from a thermometer piercing the cover, (with the bulb close to the specimen). Lower temperatures were obtained by supporting the chamber in a salt and ice water bath. High temperatures were furnished by fitting the chamber into the top of a paraffin oven. For many of the heart rate counts laboratory light was sufficient; for others, a diffuse, water-filtered beam from a microscope lamp was directed into the chamber.

Except at the damaging extremes, *Grylloblatta* was exposed for an average of 17 minutes to each temperature level. *Thermobia* was exposed for an average of one hour and ten minutes at each level. At least two readings were made for each temperature, but three or many more were made in most cases. No specimens were used for further recordings, afer being exposed to temperatures that might be considered damaging. In all cases the rates for previously known temperature preferenda were obtained before subjecting a few individuals to lethal limits. During each run it was frequently noticed that struggles or movements of the alimentary tract produced marked irregularities or even brief cessations of heart activity.

Results

A. *Oxygen consumption:*

Grylloblatta.—The oxygen consumption of *Grylloblatta* at various temperature levels throughout the range −2.5° to 20.5°C is given in Figure 1. The animals remained active for a number of hours at −5.0°C though the oxygen consumption at that temperature was not measurable by the techniques available. The metabolism-temperature curve for *Grylloblatta* is a straight line (Fig. 1), with an average Q_{10} of 2.7. With increase in temperature there was a regular increase in oxygen consumption up to 20.5°C. At that temperature the animals became paralyzed quickly so that a full hour exposure was not realized. Subjection of the data to an Arrhenius plot gives a temperature characteristic of 14,600 calories over the range −2.5° to 20.5°C (Fig. 3).

At −5.0°C the animals were active but movement was noticeably

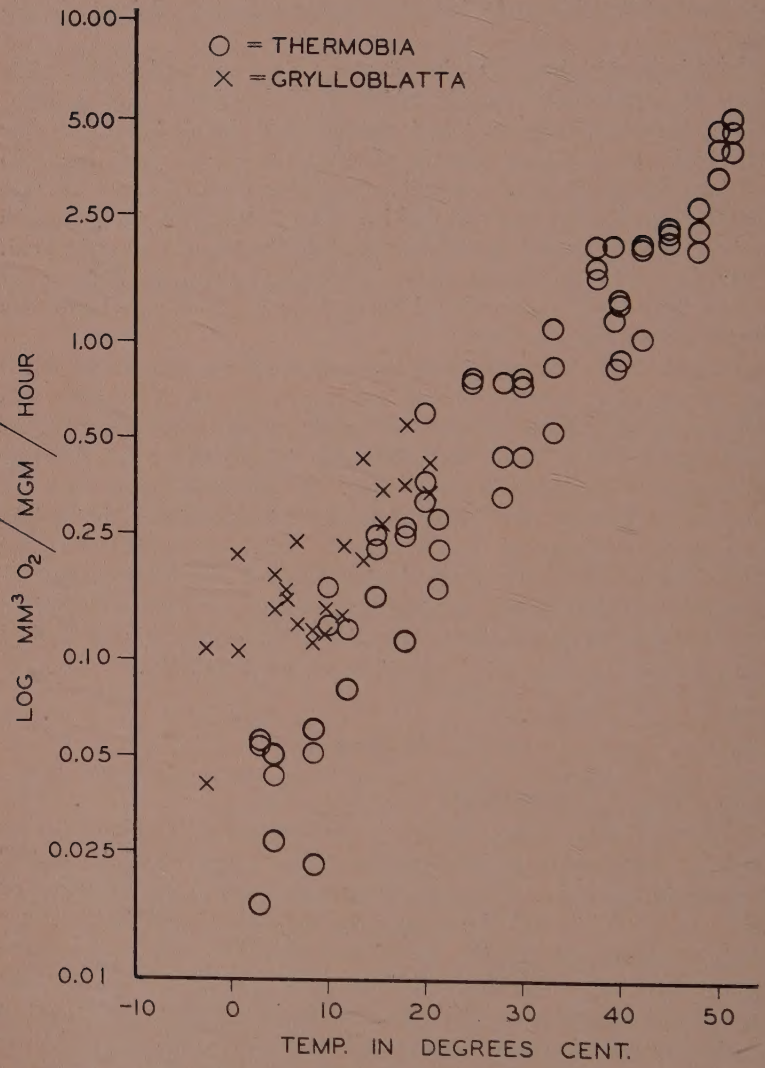

Fig. 1.—Oxygen consumption of *Thermobia* (circles) and *Grylloblatta* (crosses) over a range of temperatures.

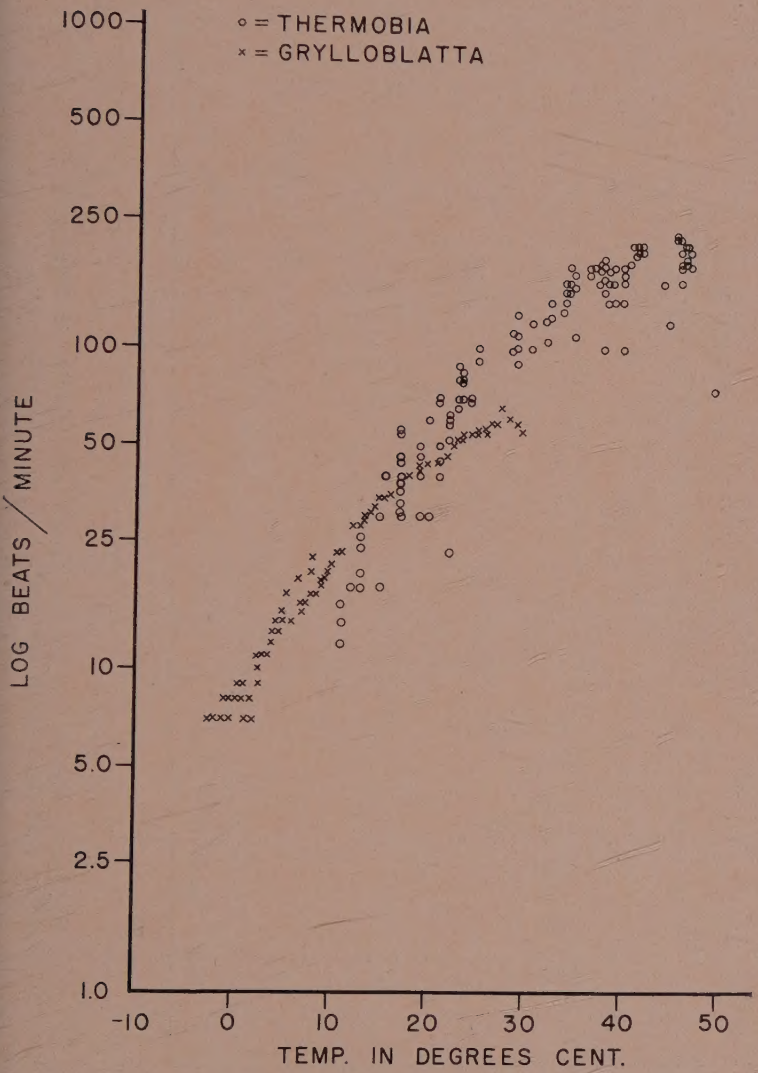

Fig. 2—Heart rate of *Thermobia* (circles) and *Grylloblatta* (crosses) ver a range of temperatures.

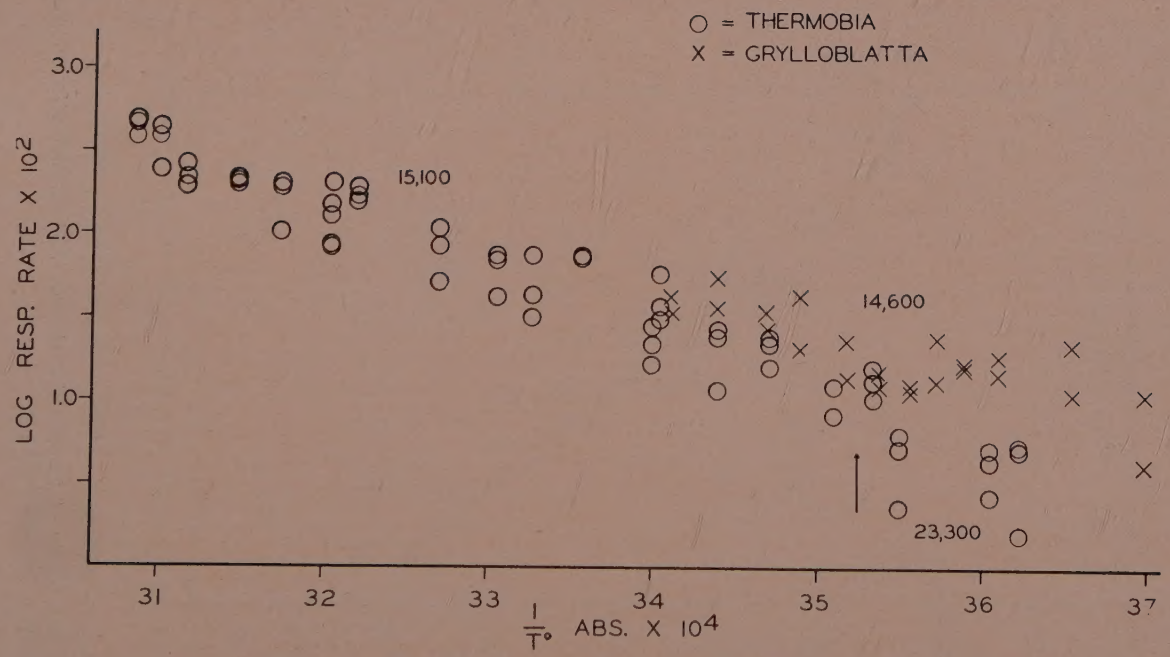

Fig. 3.—Arrhenius plot of the oxygen consumption of *Thermobia* (circles) and *Grylloblatta* (crosses).

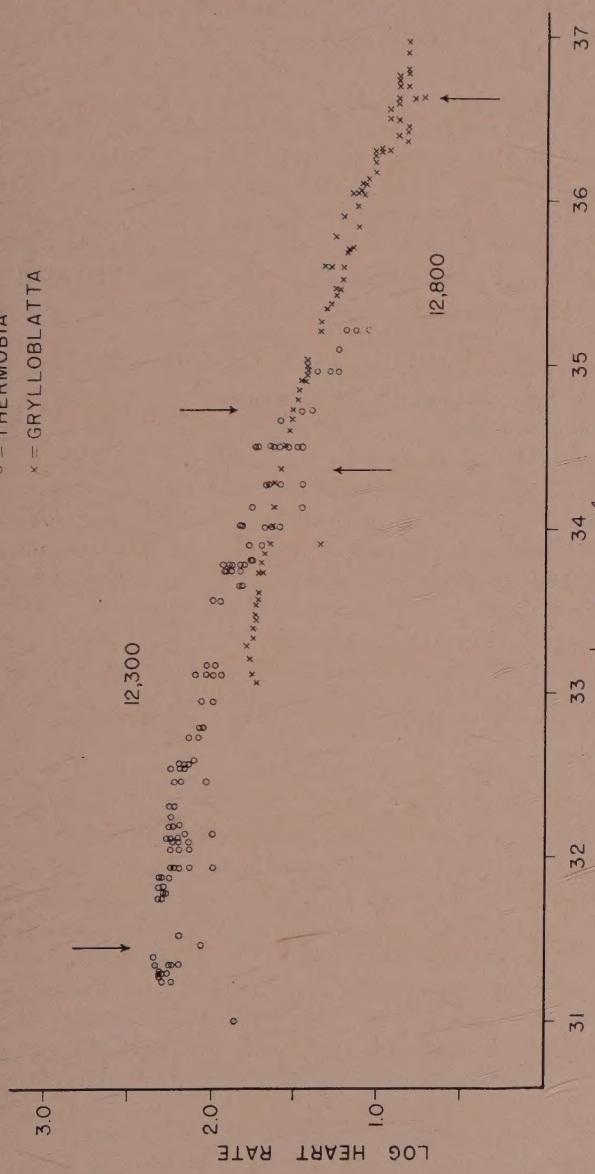

Fig. 4.—Arrhenius plot of the heart rate of *Thermobia* (circles) and *Grylloblatta* (crosses). Activation energy calculated from equation:

$$\mu = 4.58\left(\frac{\log k_2 - \log k_1}{1/T_1 - 1/T_2}\right)$$

slower than normal. In the respirometers the animals remained quiet in the range −2.5° to 11.3°C. Above this temperature they showed increased activity, struggling violently in the vessels. At 18.0°C they struggled for the first half hour and then became abnormally quiet, but still responsive to tapping. At 20.5°C the two specimens appeared to be in poor condition, moved feebly, and finally fell to the bottom of the vials and curled up after 20 minutes exposure. At this point the respirometers were shifted to a 6°C water bath and the oxygen consumption followed for an hour, during which time it fell continuously. The following day the animals were still paralyzed, showing a low oxygen consumption, feeble heart beat, and increasingly weak reponses to prodding. The female existed two and the male four days in this condition before dying.

Thermobia.—The oxygen consumption of *Thermobia* was determined at various temperatures in the range 1.0° to 51.3°C. The results are given in Figure 1.

The slope of the log QO_2—temperature curve of *Thermobia* from 12° to 50°C is practically identical with that of *Grylloblatta,* the average Q_{10} being 2.8. The temperature characteristic for this range was 15,100 calories (see Fig. 3). Below 12°C the slope increased to 3.8 and the temperature characteristic became 23,300. At 1.0° and 51.3°C the animals were irreversibly injured. Below 12°C activity was not observable, though the insects would make slow, appendicular movements when prodded. On return to room temperature, after exposure to the range 3° to 12°C, they became normally active within 3 to 20 minutes. Between 12° and 50°C activity appeared normal.

B. Heart activity:

Grylloblatta.—Over the range −2.5° to 29.5°C, heart rate in beats per minute was recorded and plotted as shown in Figure 2. The heart rate − temperature curve approximates a straight line, although there is a tendency toward levelling off and decline above 20°C, which may be due to heat damage. The average Q_{10}, figured from −2.0° to 28.0°C is 2.1. Excluding possibilities of damage and resulting deviation at temperature extremes, a mass Arrhenius plot (Figure 4) gives a slope of 2.8 over a conservative intermediate range of 0° to 18°C, with a resulting temperature characteristic of 12,800 calories.

At about 2°C the beat became rather feeble, at 0° it was hardly discernible, and after a few minutes at −3°C no form of heart ac-

tivity was observable. Up to 20°C the heartbeat was strong and regular, but after 15 minutes at 22°C diastole appeared incomplete. After 15 minutes at 27°C the heart was almost completely relaxed but continued to beat with an increasing amount of fibrillation. This type of activity was maintained for nearly 20 minutes while the temperature was raised to 29.5°C, at which point all activity ceased.

Thermobia.—The record of heart rate from 11° to 49.5°C is presented in Figure 2. The average Q_{10} calculated from 12° to 42° is 2.6. A mass Arrhenius plot (Figure 4), over an intermediate range of 15° to 45°C, gives a slope of 2.7 and a temperature characteristic of 12,300 calories.

As the temperature was lowered the heartbeat became more and more feeble, although often quite "deliberate", (i.e. with definite pauses between systole and diastole) until, with most specimens, no heart movements were visible after 30 to 60 minutes at 11°C. At the opposite end of the scale, normal heart activity was observed up to about 42°C, after which the beat became extremely rapid with incomplete diastole and intermittent fibrillation. Cessation of activity occurred between 45° and 49.5°C. General movements of the limbs and body of both *Thermobia* and *Grylloblatta* approximated those observed during the respiration experiments.

Discussion

The results show essential agreement with observations on the activity of *Grylloblatta* reported by Mills and Pepper (1937). With short exposures, they found that cold prostration set in at −6.2°, activity was observable from −5.6° to about 20°, and paralysis occurred at 24.9°, with 27.8°C being fatal. Also substantiated is their statement that *Grylloblatta* shows no dormancy at low temperatures but probably tries to avoid unpleasant conditions by sunning or seeking shelter.

The results suggest also an answer to the question of what happens to the firebrat when the fire goes out, but do not explain why the animal has a temperature preferendum so high. Data on the firebrat fit the metabolism – temperature curve of other insects for which information is available, suggesting that the wide temperature tolerance of this insect is not due to any special metabolic adaptation.

All insects thus far investigated have the same general metabolism-temperature curve, in all seasons and from all climes. The only

possible exception is the hive bee, which increases its respiratory rate and activity on either side of a preferred temperature range of 20° to 25°C (Woodworth, 1936). It was expected that *Thermobia* and *Grylloblatta* might prove to be exceptions to the rule. However, the slopes of the two oxygen consumption curves are practically identical (2.7 and 2.8); in the intermediate temperatures their respiratory rates overlap; and their Q_{10}'s are in the same range as those of all insects previously reported. They extend the general metabolism – temperature curve, and *Thermobia* most amazingly so. They are similar to other insects in that they are evidently strictly poikilothermal and utilize only supplementary insulation to offset unfavorable temperatures.

The temperature characteristics obtained over the intermediate temperature ranges agree essentially with previous work on arthropods concerning heart activity and other rhythmic neuro-muscular processes. Comparison of the two sets of data here presented, plus the fact that the heart rate temperature characteristics are not typical of catalyzed oxidative reactions, seem to support the view that respiration is not the fundamental process determining heart rate (see Fries, 1926, for further discussion and bibliography). The temperature characteristics obtained from the oxygen consumption curves are typical values for cellular respiration.

What is now needed most urgently is a thorough study of the biology of *Grylloblatta,* which would provide a firmer ground for the interpretation of data such as here presented. How does the insect manage to stay within the narrow range of −5° to 18°C in nature? Does it escape the inevitably severe sub-zero temperatures of its habitat by crawling into deep, rocky, fissures, or in and around roots and in humus where the temperature may remain close to freezing? Is it possible, however unlikely, that the paralysis preceding death at the extremes of its range may be a hibernation state? What relationship exists between the length of the nymphal stages and the low temperature range? What intra- and interspecific variations in temperature responses occur and how do these relate to distribution? A clue to the answer to the last question has perhaps been suggested by Campbell (1948). He reported that a form of *Grylloblatta* found at Kamloops, under conditions less severe than those of the Canadian Rockies and Montana, did not succumb to warmth as easily as typical *campodeiformis* usually does. This may represent lack of uniformity in temperature preferenda, but it

strongly suggests physiological adaptation and perhaps even taxonomic subspeciation.

Summary

The oxygen consumption, heart rate, and activity at various temperatures over the range −5.0° to 51.3°C have been determined for the firebrat, *Thermobia domestica* Packard and for *Grylloblatta campodeiformis* Walker.

Grylloblatta is normally active from −2.5° to 11.3°C. At lower temperatures activity is decreased and at higher temperatures activity is increased until at 18.0° the animals become stuporous and at 20.5°C become irreversibly damaged by heat. Over the range of temperatures from −2.5° to 20.5°C the log Q_{10} − temperature curve is a straight line, having the slope of 2.7 per 10 degrees. In this range the temperature characteristic for oxygen consumption is 14,600 calories. In the range −2.5° to 29.5°C the curve relating heart rate to temperature resembles the respiratory curve giving an average Q_{10} of 2.1. In the intermediate range of 0° to 18°C an Arrhenius plot of heart rate gives a slope of 2.8 and temperature characteristic of 12,800 calories.

Thermobia is active throughout the range 12° to 50°C. Below 12° it becomes inactive, and is irreversibly injured by cold at 1°C. At 50° activity decreases and heat injury becomes apparent at 51.3°C. The log QO_2 − temperature curve has a slope of 3.8 per 10° from 3° to 12°C, and a slope of 2.8 between 12° and 50°C. Temperature characteristics for respiration in these ranges are 23,300 and 15,100 calories respectively. The heart rate − temperature curve is practically identical with the respiration curve, giving an average Q_{10} of 2.6. The temperature characteristic for heart beat in the intermediate range of 15° to 45°C is 12,300 calories.

These two insects extend the general insect metabolism − temperature curve, and appear to be strictly poikilothermal in that they make no metabolic adaptation to offset unfavorable temperatures.

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The C. Andresen Hubbard Collection of Fleas of the Pacific Northwest.—Students of fleas will be interested to learn that the Museum of Comparative Zoology of Harvard University recently received from Dr. C. Andresen Hubbard a collection of carefully prepared and labeled slides representing about 75 species and sub-species of western fleas. The slides are neatly put up in a case, together with a numbered index of the forms represented and a copy of Dr. Hubbard's paper on "The Fleas of California" (1943). Appropriate gaps are left in the case for additional kinds which Dr. Hubbard intends adding from time to time to this set. It now contains paratypes of *Megabothris clantoni*, *Epitedia jordani*, and *Corypsylla jordani*. The Harvard set is Dr. Hubbard's "Depository No. 20," as he is sending similar sets to 19 other institutions here and abroad, in addition to the "Master Collection" to be deposited at the U. S. National Museum. Dr. Hubbard is to be greatly commended for his unusual generosity and foresight in distributing his material so widely so that it may be available to many present and future students of this most fascinating and medically important order of Insects.—J. Bequaert, Museum of Comparative Zoology, Cambridge, Massachusetts.

NOTES AND DESCRIPTIONS OF WESTERN CHRYSOPIDAE (NEUROPTERA)[1]

By Nathan Banks
Holliston, Mass.

For some years Chrysopidae have been accumulating in the collection at the Museum of Comparative Zoology, and in recent years I have received, with other Neuropteroids, many specimens from Grace H. and John L. Sperry, especially from California and Arizona, from Prof. A. L. Melander also material from the same states, and from P. H. Arnaud specimens from California. During the summer of 1948 two students, F. Werner and W. Nutting, made an automobile trip to the southwest and to Mexico, and captured many hundreds more.

Most of the new species are from the western part of the United States and this paper is devoted to their description.

Many of the new forms are in the *Eremochrysa* section, so I have tabulated them, and made new descriptions of some of the old species.

Genus *Meleoma*

The males of the species of *Meleoma* can be recognized by the interantennal process. In the western States are four species, to these I add three more, two of them from California; another species occurs in Arizona, but the specimen has no antennae, so I leave it undescribed.

Meleoma comata sp. nov.

A species similar to *M. emuncta* with a different interantennal piece, the wings less coarsely haired.

Green; a medium white stripe from vertex back over the abdomen; in the female there is a faint trace of a reddish stripe before the side-margin; legs greenish, tarsi soiled whitish; antennae mostly pale, first joint green. Venation green, a few crossveins dark, mostly toward wing-base; several costals toward base, and some

[1] Published with a grant from the Museum of Comparative Zoology at Harvard College.

beyond dark at one end; gradates green. Cheeks with a narrow black line, interrupted near middle; palpi with a narrow black line above on one or two joints; in the male these lines more prominent, and the basal joint of antennae pale, with a reddish mark in front toward the tip, the basal joint extends laterally over the eye; the upper edge, seen from in front very concave; the second joint is much longer than broad, constricted below the middle, the lower part bearing minute erect hairs. The third joint is elongate, swollen mostly toward the inner base, the outer edge there concave, the inner edge has the row of white curved hairs which extends, somewhat obliquely upward. The interantennal process is much broader than long, concave in front (seen from above) each side at tip extending somewhat laterally and tipped by some short bristles. On the front, just before the anterior slope, is a group of erect hairs, pointing toward the process.

The wings are more slender than in *M. emuncta,* the tip almost in a point. The hairs on the costal fringe are very much shorter than in *M. emuncta,* and those elsewhere on the venation are much fewer. In the fore wing about twenty-four costals before stigma, the cells, except toward stigma, are plainly higher than broad; the costal area (at widest) hardly equal the radial area; the divisory cell two and a half times as long as broad, ending beyond cross-vein above; below there are seven cubital cross-veins. The hind marginal area is one and one-half times as broad as the cubital, but not quite twice as broad as costal area. Seven to nine inner gradates and eight to ten outer ones, in parallel rows; each gradate separated about its length from the next. In hind wings eight gradates in each row, about parallel. Beyond the end of medius (fore wing) there are five or six forks before wing tip. Length of fore wing, 14.5 mm.; width, 5 mm.

Male and female from Upper Santa Ana River, San Bernardino Co., California, 15 July, 6 Aug., 1948. (G. H. and J. L. Sperry). Also an old female from San Bernardino Mts., South Fork, 20 June, 6000 ft. (Grinnell).

Type: M. C. Z. no. 28348.

Meleoma cavifrons sp. nov.

A small, slender-winged species, with few cross-veins, basal joint of antennae erect, and, seen from in front, each side convex, the

male with almost entire front forming a large heartshaped concavity.

Body and wings pale yellowish, female rather more green, a broad black stripe on cheek, scarcely interrupted; palpi lined with black; pronotum broadly reddish brown on each side; third antennal joint scarcely longer than second or fourth, not modified; second joint constricted below middle; vertex with the median raised area margined on sides and front by a dark line. Basal joints of antennae hardly one-half their diameter apart, erect, and sides convex, in both sexes alike. The interantennal process is slender between antennae, but widened and forked in front, each arm with bristles at tip; below there is a great, heart-shaped concavity occupying almost entire dorsal surface of face, each upper corner reaching to the eyes; its surface and margin bears erect, short hairs, and below tip of interantennal process are two tufts of long, erect hairs; pronotum narrowed in front, behind as broad as long.

Wings about three and one-half times as long as broad, tip nearly in a point; venation open, but eighteen to twenty costals, and only nine or ten radial cross-veins, mostly dark. Medius to tip of the second cubital cell is dark, also the basal part of the radial sector; branches of radial sector dark on basal part; also dark are the gradates, cubital cross-veins, and branches of anal vein near wing base; marginal veins pale. In hind wings not so many veins dark. The costal fringe is moderately long, but much shorter than in *M. emuncta;* hairs on cross-veins but few. Divisory cell ends at the cross-vein above.

The costal cells are higher than long, except near the stigma; radial cells about as long as high; the gradates in parallel rows, inner of three or four, outer of five, each widely separate from the next. Beyond the end of the medius but two and one-half forks before wing-tip. Length of fore wings, 11.8 mm.; width, 3.7 mm.

Male type from Pinecrest, Tuolumne Co., California, 10 July, 1948. P. H. Arnaud, Jr., collector.

A female taken at the same locality, but on 19 July, is apparently the same species. The head and a median stripe on the pronotum are whitish, elsewhere and wings green. Nine radial cross-veins as in male, and other venation similar; the costal fringe longer than the male, but six cubitals beyond the divisory cell; basal antennal joint as in male; of same size.

Type: M. C. Z. no. 28350.

Meleoma delicata sp. nov.

A small species, the third antennal joint not modified, the basal antennal joint, slender, enlarged at tip in usual manner, but with a flat area or scar at tip; nearly all of the cross-veins are dark.

Pale greenish, abdomen green, wings hyaline, cross-veins and branches of anal are dark. Basal antennal joints hardly diameter apart, cylindric, from in front outer side concave, somewhat shorter than usual, with a swelling near tip in front. Interantennal process broad, nearly truncate at tip, below it is a broad cavity, each side reaching to eyes, but not long, and reaching scarcely one-third way to tip of head; the margin is bordered with hairs, and a central group of hairs a little in front of it; from the side an erect process is seen, with an upcurved tip, pointing toward the front of the interantennal process. In certain views the upper outer corner of the basal antennal joint shows a short spur. Pronotum short, brown, with a pale median line.

Wings sparsely veined, but hardly as much so as *cavifrons*. Costal area quite broad, but the radial area broader, and about equal to marginal; cubital area almost as broad as costal; tip of wings almost in a point.

Practically all cross-veins, and the gradates dark, or at least partly so, also the anal branches. Divisory cell about two and one-half times as long as broad, ending beyond the cross-vein above. Twenty costals before stigma, the cells higher than broad, except those toward stigma; eleven radial cross-veins, three cells near middle higher than broad; gradates parallel, seven in each row, mostly about their length apart; six cubitals beyond the divisory; hind margins of fore wing with four forks beyond end of medius and before tip of wing. Costal fringe fairly long, hairs on cross-veins few and rather short.

In hind wings the costal cross-veins and the radials mostly dark, nearly all the other venation greenish; six inner gradates, seven outer rows parallel. Length of fore wing, 12 mm.; width, 4 mm.

A male from Ft. Wingate, New Mexico, 14 August 1908, John Woodgate.

Type: M. C. Z. no. 28349.

Another male from two miles southwest of Patagonia, Santa Cruz Co., Arizona, 30 July 1948 (Werner and Nutting).

Chrysopa pinalena sp. nov.

Head rather short and broad, pale; directly below the antennal sockets is a transverse dark brown band from eye to eye, it bends upward in the middle, below it on the clypeal edge is another and similar band, almost as broad, reaching from eye to eye, and also bent up in the middle, a little more than the upper band; below this in the middle is a short, slightly down-curved brown band. At each end of both complete bands the dark is enlarged. In the specimen figured the antennae are strongly thrown back, in one with the antennae porrect, the upper band is almost hidden. Palpi black, with pale tips to the joints(except last); antennae (including second joint) pale, unmarked. Vertex rufous, and somewhat swollen in middle, leaving only a very narrow groove between it and the eyes. Pronotum narrowed in front, longer than broad, at least a little; pale in middle, dark on sides, broadly so behind; also the meso- and metanotum pale in middle, the lateral lobes dull black. Legs pale, unmarked.

Abdomen pale below, and mostly on the sides; above with several segments toward base with a large dark mark, sometimes the marks hardly distinct.

Fore wings with anals black, the subcostal vein toward, but not at base and the upper side of third cubital cell dark, other veins slightly darkened, but often only at bases of hairs; gradates no darker than others.

Stigmal area darkened for a long space, and with five to seven subcostal cross-veins; twenty-four or twenty-five costals, twelve radials, four or five inner, and six to eight outer gradates, subparallel, the inner as near radial sector as to outer, seven branches of radial sector reach outer margin. Divisory cell slender, ending much beyond the cross-vein above, seven cubitals beyond the cell. Hind wing very similar, with seven branches of radial sector to margin, and one or two fewer gradates. Length of fore wing, 13.5 mm.; width, 4 mm.

Two specimens from the Pinals, Globe, Arizona, 18 July 1948. (Nutting and Werner).

Type: M. C. Z. no. 28345.

Chrysopa yuma sp. nov.

Body green as also venation, legs and antennae. Face scarcely marked; there is a very faint reddish tinge under the base of each

antenna; there is no cheek mark, nor any spots on the clypeus; palpi wholly pale green. Antennae entirely pale greenish, no marks on basal nor second joint; in one specimen the vertex is faintly yellowish in front; the subtriangular elevated area is rather smaller than usual, the groove between it and the eye being quite broad.

Pronotum nearly twice as broad as long, sides parallel, but in front narrowed at the head. Legs short, pale, unmarked. Abdomen of female about as long as usual, in male not reaching half way to tip of wings, its tip rounded. The hairs on abdomen (and pronotum) are wholly white.

The wings of male are almost acute at tip, but more rounded in female. The venation is the usual *Chrysopa* type; the sub-costal cross-veins at stigma weak and few. Sixteen costals before stigma, eight radials; costal area only a little more than one-half the width of the radial area; marginal area much broader than cubital; divisory vein ends beyond the cross-vein above, but five cubital cross-veins beyond; three or four outer gradates, and one inner, about the same in hind wing. The third cubital cell has two branches to the hind margin, and the next cell beyond but one branch (as normal *Chrysopa*).

The costal fringe is quite long, but not dense, the hairs on the veins are long, but not numerous. Length of fore wing, 8.5 mm.; width, 2.8 mm.

Male and female from Ft. Yuma, California, 6 June, 13 June, Andahl collector, from G. H. and J. L. Sperry.

This insect has no near relation to the *plorabunda* section of *Chrysopa,* which are almost wholly green. It has no sinuous costal cross-veins found in that section. The venation is more open than the usual *Chrysopa.* In the male the apical part of wing is more narrow and there are but three branches of the radial sector that reach the outer margin of wing.

Type: M. C. Z. no. 28346.

Chrysopa clarivena sp. nov.

Pale; no marks on face nor cheek; basal antennal joint unmarked, second joint black, beyond faintly darkened; basal joint rather short and broad at base, little separated from each other, palpi pale, last joint darkened. Vertex with a red mark each side by eye, middle area elevated.

Pronotum pale, with sides parallel, but in front narrowed; no distinct marks; meso- and metanotum dull, pale brownish; legs wholly pale, hind femora unmarked. Abdomen pale, dull gray to brown above with the apical three segments pale yellowish, below with only the apical segment pale.

Wings hyaline, with hyaline or whitish (perhaps greenish alive) venation, the base of the second cubital cell and the cross-vein below it in certain views dark; no sinuous costal cross-vein; the costal area, which, at broadest, is much more than one-half of radial area, has three long cells near base (fourth, fifth, and sixth) which are almost or fully as long as high and beyond are several cells longer than usual. The divisory cell very slender, narrowed at base, and ending beyond the cross-vein above, six cubitals beyond the divisory cell; two inner gradates and five outer, the inner much nearer to outer than to the radial sector. Three branches of radial sector reach to margin, tip of fore wing rounded, that of hind wing plainly acute; costal fringe fairly dense and of moderate length, hairs on veins rather few and quite long. Length of fore wing, 10.2 mm.; width, 3.7 mm.

One specimen from Ehrenberg, Yuma Co., Arizona, 11 July 1948, mesquite area (Nutting and Werner).

Type: M. C. Z. no. 28347.

This species is peculiar in the long costal cells, but not unique; this character is found in *Chrysopa apache* Bks., and in *Chrysopa yuma,* the small green species described in this paper. For them I make a new subgenus with *Chrysopa apache* the type. It is based on the character of having especially long cells at the widest part of the costal area, at least one of them being as long as high; the antennae beyond the second joint, tend to be darkened, and the inner gradates much reduced, sometimes none; the number of branches of radial sector to reach hind margin is reduced so that the wings tend to have the shape of *Eremochrysa.* The three species now known to belong to this subgenus *Yumachrysa,* are *apache* with venation almost wholly dark, longitudinal as well as cross-veins, and the hind femora have a black band. The others, *yuma* and *clarivena* (described in this paper) have almost wholly pale venation; *yuma* with the radial area but little broader than the costal, and *clarivena* with the radial area much broader than the costal, elsewhere also broader.

Genus *Eremochrysa*

This genus is represented in the western part of our country by many species. All have the cross-veins more or less darkened, and often the longitudinal veins dotted. As a rule the wings are less widened apically than in *Chrysopa,* and the tips more rounded. In *Chrysopa* the branches of the radial sector which reach the outer wing-marking are forked beyond the outer gradates, in *Eremochrysa* rarely more than one is forked beyond the outer gradates.

The males have an extension at the lower end of the abdomen, not present in *Chrysopa;* in one group this process is upcurved, and with simple hairs, in the other group the process is straight and provided with reclinate hairs or bristles.

Table of Species of *Eremochrysa*

1. Front and mid tibiae with a dark cross-band about one-third way from base, often also a dark spot at base of these tibiae; venation mostly dotted, vertex usually with reddish lines or spots .....*tibialis* sp. nov.
   Front and mid tibiae without dark band.....2
2. Antennae just beyond second joint with several joints black or with a black band; face with a reddish stain under bases of antennae.....*rufina* sp. nov.
   Antennae beyond second joint not at all black.....3
3. Veins and many of the cross-veins dotted with dark.....4
   Veins not dotted, cross-veins mostly entirely dark.....5
4. Face often with yellowish or reddish marks (sometimes united) vertex with reddish lines or spots; fore wings rather broad so that four or five of the branches of radial sector reach the outer margin.....*punctinervis* McLach.
   Face usually without marks, vertex mostly rufous, at least in front, and few if any lines or spots; the apical part of wing more narrow so that only two or three branches of radial sector reach outer margin.....*pumilis* sp. nov.
5. Four or five branches of radial sector reach margin; usually black or dark marks on face and vertex, and three stripes on the basal joints of antennae, and three on pronotum.
   fraterna Bks.
   But two or three branches of radial sector reach outer margin. Not so heavily marked, few marks on face or pronotum.....6

6. Vertex at least in front rufous, no marks or few; cross-veins of fore wings rather fine, face with few or no marks.
rufifrons sp. nov.

Vertex mostly pale, with reddish or darker lines; face below antennae more or less plainly rufous, cross-veins of fore wing noticeably heavy.....*altilis* sp. nov.

Eremochrysa punctinervis McLach.

Female.—Head with line below each eye extending towards mouth; a row of three black spots (often connected) across clypeus; below antennal sockets usually a transverse band (yellowish to rufous); a black spot between the bases of the antennae, and extended behind on vertex as two slender divergent lines. Palpi partly dark. Basal antennal joint usually with one nearly complete dark line and one or two dark spots; second antennal joint with a dark ring.

Pronotum with two broad brown or reddish brown spots on each side, usually more or less connected, and sometimes with median extensions; usually a dark median line; meso- and metanotum usually with dark or black spots laterally.

Wings with both longitudinal and cross-veins dotted with black (dark), sometimes some of the cross-veins are wholly dark, especially the costals; the markings are more prominent on the fore wings, and sometimes venation of hind wings is almost wholly pale. The hairs on pronotum are short and black, on the abdomen often longer but mostly, at least, black.

The males are usually less completely marked; at the tip of the abdomen of the male there is a lower process, projecting more or less conical, and provided with short hairs among which are some reclinate stiff bristles, some almost spine-like.

The type is from Texas, but the species is widely distributed in the western states, most common in the southern ones; eastward it extends to Florida.

Eremochrysa fraterna Bks.

A long black streak on each cheek; three, usually elongate, dark spots form a line across clypeus; below antennal sockets sometimes a transverse dark line, or often broken in middle; between the antennae two dark (black) lines extend up and on the vertex and

diverge; often a dark line along inner edge of eyes. Palpi mostly black, including last joint. Basal antennal joint with two stripes nearly black, and very prominent, usually also a third shorter stripe; second joint with a black ring or more fully black; rest of antennae pale for some distance, but toward tip often a stretch of nearly black joints.

The pale legs nearly always have a dark spot on under side of the femur near tip, most prominent on hind legs; sometimes the tibiae show a cross-band of brown near base. Hairs on pronotum mostly black, and also most of those on the abdomen.

Fore wings with many of the cross-veins, and the gradates wholly black, especially costals and radials; longitudinal veins often also may be almost wholly dark, but in many cases they are dark at connections and elsewhere more or less dotted. Radial area plainly a little broader than costal area, marginal area plainly broader than cubital area, six cubitals beyond the divisory cell, latter not much narrowed at base, ending beyond the cross-vein above. About eighteen to twenty costal cross-veins; three or four subcostal cross-veins at stigma, and each dark and bordered with yellowish brown; gradates two to four inner; and about as many outer ones, well separated. Sometimes the cross-veins are not entirely black, especially in teneral specimens.

At the tip of the abdomen of the male the lower projecting piece is larger and less tapering than in *punctinervis*.

This species occurs over most of the western states, and often in mountainous areas, but not as common as *punctinervis*.

Eremochrysa rufina sp. nov.

Face with a reddish fan-shaped mark under antennae, broad below, ending on each side in three branches, other small reddish spots on lower face, palpi marked with dark; vertex with a narrow angulate line above antennae, another across the front margin of the elevated area, also somewhat irregular marks each side on the elevated area, and a reddish spot each side close to eye. Antennae not marked on basal joint, second joint faintly rufous, about three joints beyond are black, and four or five with a basal black ring.

Pronotum narrowed in front, each side broadly dark reddish; rest of thorax and abdomen above dark reddish-brown, the abdomen near tip with some white spots; pleura and venter pale; hairs white, as also on pronotum; legs pale, unmarked. Wings with dull brown

cross-veins and gradates, longitudinal veins pale, without dark dots; in hind wings the dark less distinct; stigma somewhat infuscate, but the cross-veins not bordered. Tip of hind wing pointed, that of the fore wing more broadly rounded; venation very similar to the other species; the costal area rather narrow near base; three inner and four outer gradates. Hairs on veins about as in allied species. The divisory cell is shaped much as in *Nodita,* with a broad, oblique base.

The process at tip of abdomen is shorter than in the other species, and projects only a little; it is densely long-haired and I see no reclinate bristles, but there are raised conical processes tipped with a stiff hair (best seen on lower edge). The elliptical pale lobe on side of last segment is larger than in the other forms. Length of fore wing, 10 mm.; width, 3 mm.

One male from Grand Canyon, Arizona, 24 July.

Type: M. C. Z. no. 28351.

Eremochrysa tibialis sp. nov.

Head, thorax, legs whitish; face with a reddish mark each side, divided inwardly; the upper, narrow part borders the antennal socket, the lower and broader reaching nearly to middle of face; clypeus with a dark median spot near lower edge, and a larger black spot at upper corner of clypeus, and extending a bit onto clypeus; cheek with a broad, dark brown (or rich brown) stripe, reaching to upper edge of clypeus; palpi dark, except tips of the joints. The basal antennal joint has a short black line or spot toward the inner tip; a black line on outer side and one above, and the second antennal joint dark (rich brown). The vertex has a dark spot each side on the raised area, with a short line extending forward, and a long dark spot close to the posterior part of eye; the collar (below the front of pronotum), has two dark brown marks on outer side.

The pronotum has a dark margin (formed of dark lines), broken near middle; there is a dark dot near the middle of front margin, another at middle before the cross-groove, and two behind the groove. The lateral lobes of meso- and metanotum have dark spots, and one on each lateral corner of the mid-lobe of mesonotum. Legs pale, all the tibiae have a dark dot near base, and a dark cross-line about one-third way down; the hind femur has a small dark spot near end.

The abdomen above is dull yellowish, with narrow dark hind

borders on the segments, broader on the fourth and fifth segments. Pleura and venter dull, with a broad pale border to the fourth and fifth segments; the last two segments wholly pale. Apical process of male straight and rather stout, but tapering, with reclinate bristles, and some long, simple hairs. The tip of upper part has long, slender hairs; elsewhere the numerous hairs are extremely minute and very short, shorter than in *E. fraterna.*

The venation is mostly pale, with numerous dots, a few of the costals wholly dark; gradates partly dark, three inner, four outer. The divisory cell, rather slender, ends on the cross-vein above. Fifteen costals; eight radials; gradates parallel, inner about as near to radial sector as to outer series. In this male there is but one cross-vein from the third cubital cell to margin, two from the fourth cubital cell. Length of fore wing, male 8.5 mm.; female 9.5 to 10 mm.

A male from Florence Jct., Arizona, 18 April 1935 (F. H. Parker) and many specimens from Watson, Utah, 22 July (F. M. Carpenter), also Vidal, California, 9 April (Sperry).

Type: M. C. Z. no. 28358.

Eremochrysa altilis sp. nov.

Head pale, face below antennae to the clypeus almost entirely reddish brown; a pale spot between antennal bases, and a smaller one on middle of clypeal margin; three dark spots on clypeus, one each side, and a median one, higher up. Below each eye is the usual dark brown stripe on the cheek; palpi reddish-brown, tips of joints, and basal joint pale; basal joint of antennae has a dark stripe on outer side, and a much shorter one on inner side; second joint not darkened. Rest of antennae whitish, but toward tip some joints are partly dark.

Pronotum longer than broad, sides parallel, rather broadly dark, mesonotum and metanotum with dark spots; legs pale, hind femora with a rather broad red-brown band a little before the tip.

Abdomen grey, somewhat marked with darker above; tip pale; the lower piece of male is rather broad and tapering but little until near the tip; it bears many reclinate bristles, and below near base is a group of erect hairs, the upper tip of abdomen is thickly clothed with long white hair, much shorter white hairs elsewhere.

Wings shaped as in *E. fraterna,* a broadly rounded tip, no acute point; costal area quite narrow; thirteen costals, before stigma,

marginal area scarcely more narrow than the cubital, six radial cross-veins, four outer gradates, these close to wing-tip; no inner gradates. Cross-veins wholly dark brown, longitudinals pale, unmarked except at joinings. Three stigmal cross-veins dark, but scarcely bordered; hind wings also with the cross-veins dark, and the longitudinal pale, except at joinings.

A female is similar, but the mark below antennae does not occupy the whole area; pronotum as broad as long. Length fore wings, male 6.5 mm.; female 8 mm.

One male and several females from Stockton Pass, Pinaleno Mts., Graham Co., Arizona, 5440 ft. (Nutting and Werner).

Type: M. C. Z. no. 28357.

Eremochrysa rufifrons sp. nov.

Face whitish or pale yellowish, usually the three clypeal dark spots and a slender cheek-mark; basal antennal joint with an outer black stripe, and one on the inner side, none above, second joint of antennae more or less darkened; palpi mostly black, with more or less distinct pale bands; vertex more or less rufous in front, shining. Legs pale, hind femur with a dark mark near tip.

Pronotum usually a little longer than broad and tapering slightly in front; pale, dull yellowish, no marks on side nor band across, but in front are two small dark spots, sometimes faint. Meso- and metanotum and pleurae also pale yellowish, without marks. Abdomen also pale, unmarked. Hairs on pronotum dark, those on abdomen mostly pale, but in females there are some black bristles on the dorsum of some segments near tip of abdomen; in the male the hair on abdomen is white and very short.

Fore wings with cross-veins wholly dark, some toward base are often more broadly dark; the longitudinal veins are pale, except at endings of the cross-veins, no dots. Stigma but little darkened, and the three cross-veins not strongly marked. The wings are not broadened before tip as much as in *E. fraterna,* there being but two or three branches of radial sector to reach the outer border.

Twelve or thirteen costals, six or seven radials, two or three inner gradates and three or four outer ones. The divisory cell is slender and ends well beyond the cross-vein above, six cubital cross-veins beyond. In the hind wing the median and cubitus are united for a long distance near base; no inner gradates. Length of fore wing, 8 mm.

From Globe, Arizona, 9 August 1933 (Parker 34), also Globe, Arizona, 19 July, at light (Werner and Nutting).

Type: M. C. Z. no. 28356.

In structure and color of veins, this species is close to *E. fraterna,* but readily separated by the absence of markings on pronotum and rest of thorax, and on the vertex, and absence of a stripe on the upper side of basal antennal joint.

Eremochrysa pumilis sp. nov.

Face pale whitish or yellowish; usual black cheek-mark, clypeus with a dark spot each side, a larger median spot, no marks on face. Basal antennal joint with a black line on outer side, and one on inner side; second joint dark above. Vertex pale, with two more or less distinct dark spots on middle area, and a dark spot each side close to eye.

Pronotum with distinct dark border each side; in front at middle a short dark line, and behind usually some traces of its continuance; a black point each side near the middle on the transverse groove. Meso- and metanotum show dark marks on the lateral portions above, and also on sides. Legs pale, a small dark mark near tip of hind femur; palpi banded with dark.

Abdomen pale; hairs mostly pale, black and longer on the segments near tip, in male almost all very short and white. The wings are moderately slender; the costals (about fifteen), the radials (eight or nine), and gradates are dotted, all are fine, not bordered, a few cross-veins toward base wholly dark. Usually four in each row of gradates; but two or three branches of radial sector reach the outer margin. The stigmal area is colored, and the subcostal cross-veins darkened.

The lower process of the tip of abdomen of the male is rather large for the small insects, and rather blunt at tip with fine apical hairs, and before with recurved bristles. Length of fore wing, male 8 mm.

Type and two others from Garland, Colorado, July (Yarrow), other from Eureka, Utah, 17 July (Spalding); Chisos Mts., Texas, 9 to 12 July (Nutting and Werner).

Type: M. C. Z. no. 28355.

Lolochrysa subgen. n.

A species (male) I described in 1903 as *Eremochrysa hageni* from Texas was, I noted, different from the other forms. I now see that the male has the lower process at the tip of abdomen long, slender, upcurved, and at tip has only short fine hairs, none of the short, reclinate bristles of the normal *Eremochrysa*. The hairs on pronotum are longer and white and that on the abdomen is also long and chiefly white. The raised area on the vertex occupies almost the whole vertex. There is none of the dotting of the veins, these being dark only at connections; the tip of the wings is very broadly rounded. In the female there is no median spot on the clypeus.

For *E. hageni* and related forms I propose a new subgenus—*Lolochrysa*, with *E. hageni* as type.

Table of Species of *Lolochrysa*

1. Antennae without marks on first and second joints; no face marks, except a black dot between antennae, and faintly on sides of clypeus; palpi pale, unmarked.....*californica* Bks.
   Antennae have the basal joints with lines on side or broad upper surface brown or darker, palpi mostly black (except *pima*) 2
2. Upper surface of basal joint almost wholly brown.....4
   Upper surface of basal joint largely pale, but a black line....3
3. Pronotum mostly white, a deep black spot (quite large) in middle of front margin, another at each hind corner; palpi mostly black.....*spilota* sp. nov.
   Pronotum brown, with a black line across, connecting three small black spots; palpi mostly pale.....*pima* sp. nov.
4. Costal cross-vein almost wholly pale, dark only at sub-costal end; costa also very pale, unmarked; fourth and fifth segments above pale, with dark preapical band.....*hageni* Bks.
   Costal cross-veins wholly dark, and costa also somewhat darkened 5
5. Upper edge of the abdominal process bordered with black, many cross-veins bordered; but three branches of radial sector reach the outer border of wing; hair on abdomen white and rather short, pronotum narrowed in front..*yosemite* sp. nov.
   No dark border to process; cross-veins not bordered, fine;

four branches of radial sector reach outer border; hair on abdomen white, and plainly longer; pronotum not narrowed in front.....*canadensis* Bks.

Eremochrysa (*Lolochrysa*) *hageni* Bks.

The type is a female from Austin, Texas; another female from the same locality agrees with it, as below.

Face white, a black spot on each outer side of clypeus; cheeks with a very broad black stripe, tip joining the clypeal black spot; palpi plainly black; a black spot between antennae, extending a little below on face, and above antennae spreads widely on the front of the elevated part of the vertex, and fades gradually behind; basal antennal joint has a broad brown mark covering the upper side of the joint; second joint with a dark ring at tip; beyond, the antennae are pale.

Pronotum with three dark spots on each side-margin, one in middle of front margin, and another opposite the second spot of the side, the two in middle may be united by a dark line. Lateral lobes of meso- and metanotum darker. Legs very slender and very pale. Hair on pronotum mostly white.

The abdomen is mostly pale, many clear white spots, the second and third segment dark above, and also the sixth and seventh. Venter wholly pale, with white hair.

Wings with broad, rounded tips as in allied species; venation as other species of this subgenus.

The costal area not nearly as broad as the radial, and the marginal very much broader than cubital area; two inner and four outer gradates; at the stigma the subcostal area is more than twice as broad as the costal area, and with three cross-veins not margined; fifteen costals before stigma, eight radials. The longitudinal veins are pale, dark only where touched by a cross-vein; the cross-veins are mostly dark, but the costals are almost entirely pale, only a few dark at the subcostal end; the costal vein is also pale. Length of fore wing 9 to 9.5 mm.

The types are from Texas; I have another from Austin, Tex.; two from Eureka, Utah, 26 July (Tom Spalding); one from St. Augustine, New Mexico (Cockerell 2102); and one from Globe, Arizona, 14 April (Parker). The head and antennae are much like eastern specimens of *E. canadensis,* but the markings of pronotum,

and abdomen, and the entirely dark costal cross-veins readily separate them.

Eremochrysa (Lolochrysa) spilota sp. nov.

Pale yellowish to greenish white, almost white on thorax; a short black streak below each eye, a black spot on each lateral corner of clypeus (no middle spot), face below antennae unmarked; basal antennal joint with three black stripes; one on outer side, one on upper side, and one (often short) on inner edge; sometimes a pair of rufous streaks on raised area of vertex, and a prominent black spot each side near eye. Palpi mostly black. Pronotum white, with a large diamond-shaped spot on middle near front margin, toward anterior corner a small black spot, in the transverse groove near middle are two black dots, a fairly large black spot on hind margin each side; seen from side a black spot in front and another near middle of the edge. Mesonotum with a prominent black spot near base of wing, the cavity each side behind is black. Metanotum with a small black spot on each lateral lobe.

Legs very pale whitish, the tibia in front with a black dot near base, and lower, but before middle, is a narrow black line across. Abdomen a dull yellowish grey, no dark marks. Hair on pronotum and abdomen white, and rather longer than usual.

Wings clear; the veins marked with dark, outer end of costals dark, two subcostals in stigma broadly dark. The cross-veins and gradates rarely wholly dark, most cubitals and marginals only dotted; longitudinal veins unmarked except a dot at junction of a cross-vein. The fore wings are proportionally broader on outer part than in *punctinervis*. The divisory cell slender, ends at or near the cross-vein above; six cubitals beyond. Seventeen costals before stigma, eight or nine radials; three inner and four outer gradates. Costal area near base broader than in other species, almost or quite as broad as radial area; marginal area much broader than the cubital; tip of fore wings very broadly rounded. Length of fore wing, 9.5 mm. to 9.8 mm.

The four specimens are from Ft. Yuma, California, 6 to 13 June 1948 (Andahl coll.) from G. H. and J. L. Sperry; another from Brawley, 8 April, California (A. L. Melander), all are females.

Type: M. C. Z. no. 28352.

Eremochrysa (Lolochrysa) pima sp. nov.

Face pale; a black streak on cheek from eye toward mouth;

clypeus with a black dot on each side, a deep black mark between antennae, below somewhat swollen, above spreading each side and connected to the broad, parallel marks on the raised area of the vertex; palpi mostly pale, basal antennal joint with a black spot on inner side above, and below an oblique mark more on upper side, no mark on outer side; second joint with a black ring, beyond, the antennae are more or less brown.

Pronotum grey, or with a little brown, with a narrow transverse black mark slightly behind middle, and with a short, blunt extension before tip in front and also one behind; the hairs short and at least mostly white, the lateral margins are narrowly black, and some black on front margin; the pronotum is almost twice as broad as long. Mesonotum grayish brown, a large black spot on the front of each lateral lobe, and extending onto the sides of the middle area. Legs pale, some black on coxae.

Abdomen beneath pale, with much white hair, above much mottled, a long black area before the tip, next to last segment above (in male) pale, with a narrow median black line.

Wings hyaline; cross-veins and gradates mostly black or very dark, cubitals sometimes pale in middle, some veins toward base may be slightly bordered with dark. The costals are usually pale on outer part. Divisory cell slender, ends beyond cross-vein above, six cubitals beyond, two to four inner gradates, three or four outer gradates. Twenty costals before stigma, eight or nine radials. Costal area at broadest much narrower than the radial area, latter about equal to cubital, the marginal area only toward base broader than cubital area. Fore wing not so broadly rounded at tip as *spilota*. Length of fore wing, 9.5 mm.

One from S. Fork Camp, White Mts., Arizona, 22 June 1947, G. H. and J. L. Sperry. The other from Santa Fe, New Mexico, Cockerell 4305.

Type: M. C. Z. no. 28354.

Eremochrysa (*Lolochrysa*) *californica* Bks.

Head yellowish; vertex somewhat reddish each side; no face marks, but the usual dark streak on cheek, and a dot between bases of antennae; a faint dark mark on extreme side of the clypeus; palpi pale, unmarked; basal antennal joint small, short, and rounded, unmarked, nor on second joint, the joints beyond are pale for about one-third way out, then becoming darker. The vertex with a short black spot each side, close to the eye.

Pronotum short and broad, roundedly narrowed in front; three small dark marks on front part, not plainly marked on sides. Rest of thorax not very plainly marked, pale above. Legs pale, unmarked, tarsi a little darker.

Abdomen pale brownish above, last two segments pale, the two before them plainly brown above.

Wings long and slender; fore wings with cross-veins, costals, and gradates brown, the veins dark only at joining; divisory vein dark and ending at or just beyond the cross-vein above. Costal area slender; some cells toward base are twice as long as broad; twelve or thirteen costals, six radials, and six cubitals, beyond the divisory cell. Between end of medius and end of radial sector but two branches reach outer margin. One or two inner and one to four outer gradates, rather far apart. In hind wing the veins are paler, but none dotted. Length of fore wing, 8 to 9 mm.

Described from Santa Clara Co., California; I have seen but one other specimen, it is from Globe, Arizona, 14 April 1935 (Parker).

Eremochrysa (Lolochrysa) yosemite sp. nov.

Face white; a broad black cheek-mark reaching to the side of clypeus; a black dot between bases of antennae; basal antennal joint dark brown on whole of upper side; second joint black. Elevated area of vertex a broad dark stripe on each side, connected in front, and a dark spot each side in the lateral groove, close to eye. Pronotum plainly narrowed in front, a little longer than broad behind; two dark spots near front margin, with a streak reaching back, a spot in middle of each side margin, a spot near each side connecting through the middle spot; another larger dark spot covering each hind corner. Thorax pale but with large dark spots on the lateral lobes; and on the sides, of the anterior lobe, and on its hind border.

Abdomen above black; a broad white mark on first segment above, a smaller one on second; fourth and fifth white above, with dark spots at each end, and traces of a median line; sixth and seventh black; eighth mostly black but with a pale spot over most of apical part; ninth pale. The hairs mostly white and rather short. Legs pale, the hind femur with a dark mark above near middle of length.

Wings with all cross-veins wholly dark, those on disc of fore wings plainly bordered, and a dark spot covering the origin of the radial sector. But three branches of radial sector reaching hind border;

also in the hind wing, and two much curved toward base to do it. Divisory cell ends just beyond the cross-vein above; about fifteen costals, and seven radials; two inner gradates and four outer ones, the latter fairly close to outer margin; the three stigmal cross-veins hardly bordered. Length of fore wing, 9 mm.

A male from Yosemite, California, 12 June 1931, Essig. In wing appearance it is much like *Eremochrysa altilis*.

Type: M. C. Z. no. 28353.

Eremochrysa (*Lolochrysa*) *canadensis* Bks.

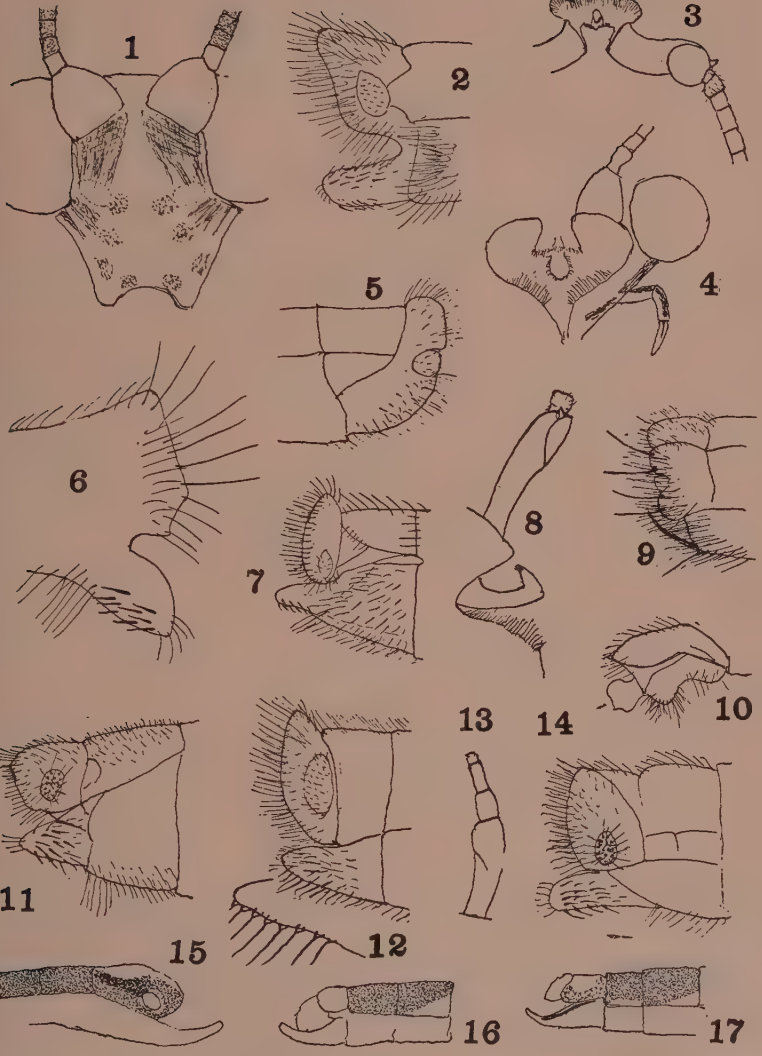
Face white to slightly yellowish, no marks; clypeus with a small dark mark on each side margin; the usual black cheek mark, broader than usual; palpi mostly black; a black spot between bases of antennae, connected to the double black mark on the front of the raised part of the vertex, sometimes with two streaks tapering behind. Basal joint of antennae with a large brown spot covering the upper side (as in *E. hageni*), no other mark; the second joint is black both in front and behind.

Pronotum is much broader than long, sides parallel, generally pale brownish, two black spots in front part, and a more or less definite row of spots across near the groove, rear corners usually black. Lateral lobes of meso- and metanotum with brown spots, legs very pale, unmarked.

Abdomen gray to yellowish below; above the first two or three segments black, then three segments mostly white, with a median black line, sometimes broadened behind, next segment black above, then the last two more or less pale, and with much long, pale hair.

Explanation of Plate 3

Fig. 1. *Eremochrysa rufina*, face. Fig. 2. *Eremochrysa fraterna*, tip of male abdomen. Fig. 3. *Meleoma delicata*, basal part of antennae, and interantennal process. Fig. 4. *Meleoma cavifrons*, face and interantennal process. Fig. 5. *Eremochrysa punctinervis*, tip of female abdomen. Fig. 6. *Eremochrysa altilis*, tip of male abdomen. Fig. 7. *Eremochrysa punctinervis*, tip of male abdomen. Fig. 8. *Meleoma delicata*, side of antennae, and lower piece of process. Fig. 9. *Chrysopa yuma*, tip of male abdomen. Fig. 10. *Meleoma delicata*, tip of male abdomen. Fig. 11. *Eremochrysa rufifrons*, tip of male abdomen. Fig. 12. *Eremochrysa rufina*, tip of male abdomen, and lower edge more enlarged. Fig. 13. *Meleoma cavifrons*, basal part of antenna. Fig. 14. *Eremochrysa pumilis*, tip of male abdomen. Fig. 15. *Lolochrysa canadensis*, abdomen of male from side. Fig. 16. *Lolochrysa hageni*, abdomen of male from side. Fig. 17. *Lolochrysa yosemite*, abdomen of male from side.



BANKS—LIMNEPHILIDAE

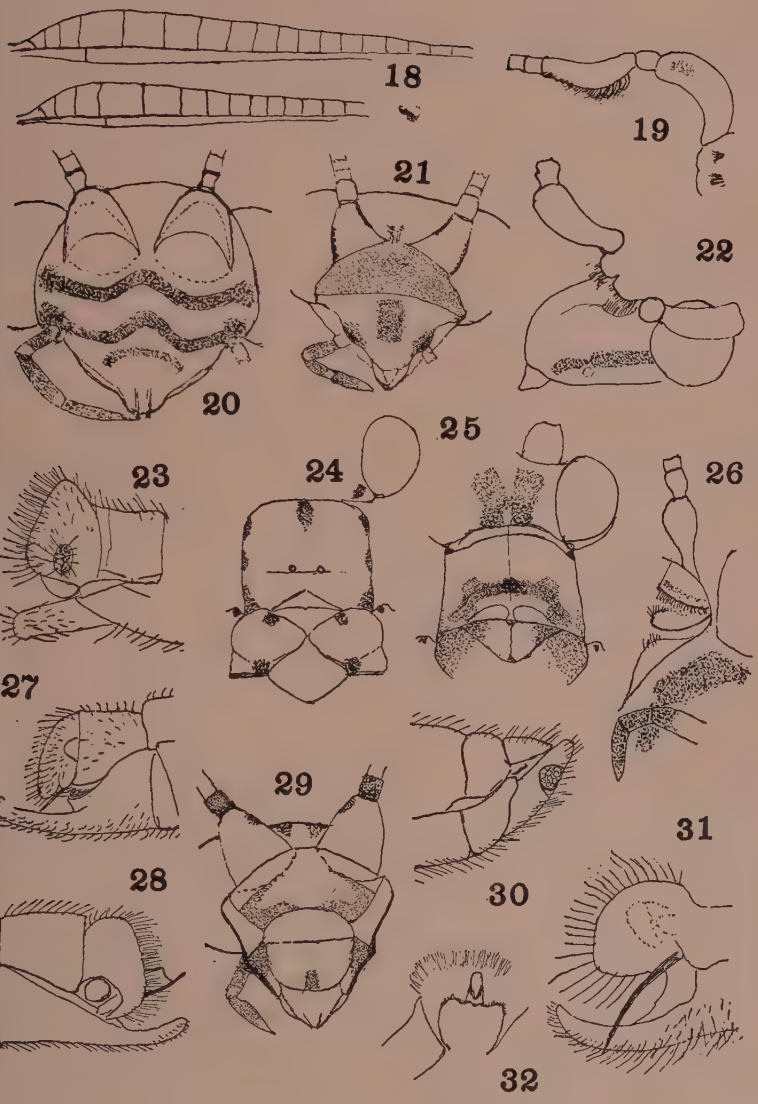
The lower edge of all the dorsal segments has a jet black stripe, which continues in a curve on the last segment; over all the segments are scattered snow-white hairs. The apical process of the male is very long and quite slender, extending more than usual beyond the tip of abdomen.

The wings are not very broad; usually but three branches of the radial sector reach the outer margin. Costal area near base is moderately broad; the costals, cross-veins, and gradates wholly brown, a cloud covers the base of radial sector; longitudinal veins pale, except at joinings, thirteen costals, seven or eight radials, and six cubitals beyond the divisory cell; the divisory vein ends a little beyond the cross-vein above; there are three to five inner gradates, about four outer ones. The inner series is nearly parallel to the radial sector, the first being about as near to the sector as the last; the three or four outer gradates are very short, and not far from the outer margin. The hind marginal area is broad so that the first few marginal cells are much more than twice as high as broad. Length of fore wing, 10 mm.

The type is from Go Home Bay, Lake Huron, Canada, 12 July; others are from Provincetown, Mass., July 1877 (Sanborn), Princeton, Mass., 16 Aug. (Johnson), Durham, N.H. (Fiske) and Mt. Desert, Me. (Proctor).

Explanation of Plate 4

Fig. 18. Costal area of fore wing of *Chrysopa clarivena* (top) and *Chrysopa azteca* (below). Fig. 19. *Meleoma comata,* basal part of antenna. Fig. 20. *Chrysopa pinalena,* face. Fig. 21. *Eremochrysa altilis,* face. Fig. 22. *Meleoma comata,* face from side, obliquely. Fig. 23. *Eremochrysa pumilis,* tip of male abdomen. Fig. 24. *Lolochrysa spilota,* pronotum and mesonotum. Fig. 25. *Lolochrysa pima,* vertex, pronotum, and mesonotum. Fig. 26. *Meleoma cavifrons,* face from side. Fig. 27. *Lolochrysa canadensis,* tip of male abdomen. Fig. 28. *Lolochrysa pima,* tip of male abdomen. Fig. 29. *Eremochrysa tibialis,* face. Fig. 30. *Lolochrysa spilota,* tip of female abdomen. Fig. 31. *Lolochrysa californica,* tip of male abdomen (type). Fig. 32. *Meleoma delicata,* interantennal process.



BANKS—LIMNEPHILIDAE

TWO NEW PAUSSID BEETLES FROM THE PANAMA CANAL ZONE AND THE PHILIPPINES[1]

By P. J. Darlington, Jr.
Museum of Comparative Zoölogy, Cambridge, Mass.

The following two new species of paussid beetles are described here for reference in other connections.

Homopterus (s. s.) subcordatus n. sp.

Fig. 1

Form average in genus; castaneous, moderately shining; most of head, pronotum, and elytra rather closely punctate with punctures of moderate size, but not obviously pubescent (some of the punctures have very short hairs which scarcely rise above the level of the body surface). *Head* across eyes (not including post-ocular tubercles) about 5/6 as wide as prothorax; post-ocular tubercles prominent; occiput only vaguely swollen; front concave, with a pair of deeper impressions within the concavity; antennae as figured, the flattened segments irregularly granulate above, more closely so on the anterior sides of the transverse segments and around the apical segment, the granules bearing short, inconspicuous hairs; mouth-parts normal for genus. *Prothorax* as figured, wide, with sides sinuate before base; disk convex, slightly swollen on each side, rather deeply longitudinally impressed at middle; disk also vaguely impressed or flattened across base and apex; lateral margins unusually broad, running into moderate baso-lateral impressions. *Elytra* rather elongate (in genus), about ¼ wider than prothorax, subparallel, with outer sides very weakly arcuate. *Femora* and *tibiae* only moderately wide in genus. *Pygidium* closely punctate; *preceding dorsal abdominal segment* more finely and less closely so. *Male* copulatory organs as figured. *Length* to apex of elytra, about 8 mm.; *width*, about 3 mm. or slightly more (both specimens too warped for accurate measurement of width).

Holotype ♂ in the Museum of Comparative Zoölogy (No. 28,369) from Barro Colorado Island, Panama Canal Zone, 5-6-37, col-

[1]Published with a grant from the Museum of Comparative Zoölogy at Harvard College.

lected and very kindly presented by Prof. S. W. Frost. One ♂ paratype in the United States National Museum (No. 59,425) from the same locality, June 1940, collected by James Zetek (original No. Z-4669).

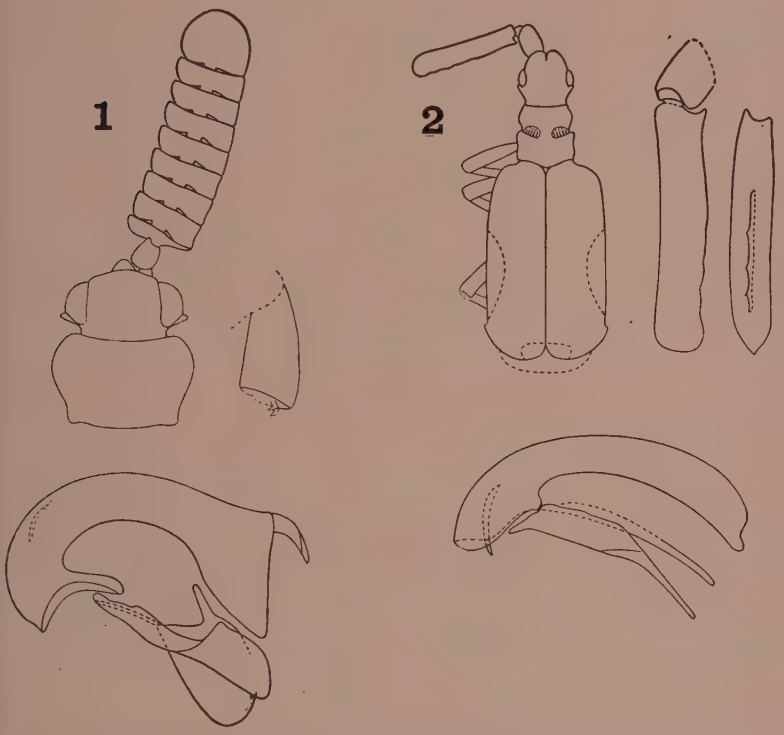


Fig. 1. *Homopterus subcordatus* n. sp. (Holotype ♂): prothorax, head, and right antenna; left hind tibia with retractile tarsus indicated; and male copulatory organs from left.

Fig. 2. *Paussus occlusus* n. sp. (Holotype ♂): whole insect; left antenna from above and (flagellum only) from behind; and male copulatory organs from left.

The subcordate prothorax, prominent post-ocular tubercles, unusually wide lateral prothoracic margins, triangular rather than rounded tibiae, absence of distinct pubescence on upper surface of body, and antennal form are characters which, combined, distinguish

this new species from all previously known *Homopterus*. The antennae are intermediate in form within the genus, with the posterior edges of the flagellar segments not so straight as in *kriegi* Reichensp., *bolivianus* Kolbe, or *brasiliensis* Westw., but not so deeply emarginate as in *steinbachi* Kolbe etc, (*cf.* Reichensperger 1938, Figs. 1-8). As compared with *H. hondurensis* Darl., which is of about the same size and general appearance and which also occurs on Barro Colorado Island (five specimens from various sources in M. C. Z. and U. S. N. M.), the present new species has a more cordate prothorax, slightly different antennae, and more prominent post-ocular tubercles, and the new species lacks the light but distinct pubescence of *hondurensis*.

I suspect, incidentally, that my *Homopterus hondurensis* (1937) and *H. kriegi* Reichensperger (1938) are the same, but a comparison of specimens will be necessary to establish the synonymy.

Paussus occlusus n. sp.

Fig. 2

Form as figured, convex; color light brown, redder anteriorly, with the following parts black or piceous: anterior and supra-ocular callosities of head, lateral and apical marks of elytra, lower surfaces of head and prothorax and (in part) mesothorax, and main portions of appendages; surface of body above (including elytra) and below dull, microscopically wrinkled; pubescence above of rather sparse, short, slightly curved, slightly thickened, yellowish hairs (this type of pubescence lacking in depressions of back of head and of pronotum, and rubbed off inner portions of disk of elytra); pubescence below of more inconspicuous, minute, pale hairs. *Head:* front with 2 longitudinal, parallel ridges anteriorly, curving in and nearly meeting above bases of antennae, and with 4 tubercles, 1 median, 1 occipital, and 1 above and behind each eye, each supra-ocular tubercle with a semicircular impression concave inwardly; antennae as figured, flagellum sub-cylindrical, with fine raised margin along anterior edge, and with the vestige of a longitudinal sulcus posteriorly under a slight ridge which shows traces of segmentation although the bottom of the sulcus does not; surface of both basal and flagellar parts of antennae closely, coarsely punctate, each puncture with a short, slightly thickened, pale hair; labial and especially maxillary palpi broad, moderately flattened, more finely sculptured and pubescent than antennae. *Prothorax* deeply, trans-

versely divided, with large trichomes in the cleft on each side, and pronotum also with a less sharply defined longitudinal depression, widest basally but deepest toward the middle. *Elytra* and *pygidium* without dense trichome-fringes or special marginal hairs; pygidial margin indistinct. *Legs* not flattened. *Male* copulatory organs as figured. *Length* (to apex of elytra), just over 7 mm.

Holotype ♂ in the United States National Museum (No. 59,426) from Biliran Island [north of Leyte], Philippine Islands, C. F. Baker Collection; unique.

This new *Paussus* goes in a group to which belong also *P. catoxanthus* Gestro, *tagalicus* Gestro, and *kolbei* Reichensperger. The group in the strictest sense may be confined to the Philippines, but it is probably related to *Paussus waterhousei* Westwood and some other Oriental-Malayan forms. The new species is probably closest to *tagalicus* (Gestro 1918), which it resembles in coloration and most other details, but the new species is distinguished from *tagalicus* by much more strongly tuberculate head and much narrower posterior sulcus of the antennal flagellum.

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A NEW SPECIES OF LIMNEPHILIDAE FROM MAINE (TRICHOPTERA)

By Nathan Banks
Holliston, Mass.

Hydatophylax victor sp. nov.

In general appearance similar to *Allegophylax subfasciatus*. Body, legs, antennae, palpi mostly pale yellowish; fore wings with a large brown or yellowish brown area, mostly over the posterior part of wing, sometimes covering the basal two-thirds of the front part also. The apical third of the discal cell and of the cell behind it remains clear whitish hyaline; this is usually connected to a similar spot in the apical part of the thyridial cell. These clear areas are constant, although the amount of dark above, before, and behind them varies.

There is a curved brown mark, somewhat before outer half of apical area, over the second and third apical cells. Sometimes the area beyond it is also darkened a little; the tips of the outer veins are also dark.

The surface of the fore wing is closely roughened as in *Allegophylax*. The venation of fore wing is similar to that of *Allegophylax,* except that the discal cell reaches almost as far back as the thyridial cell. In the hind wing the discal cell is also very slender and reaches much further basally than in *Allegophylax*. In the anal cells of the fore wing, the separation from *Allegophylax* is very distinct; the third anal cell being extremely long and slender.

The head is scarcely as broad as in *Allegophylax,* but the vertex and ocelli about the same. The pronotum is extremely short, as in *Allegophylax,* each side with tubercles and stout bristles.

The legs are also similar to *Allegophylax,* the front and middle tibiae spined to base, and on outer side a few spines near base. The hind legs are long; the tibiae spined a little before middle; the last joint of hind tarsus has one or two spines below.

The male genitalia has a pair of slender processes from the lower base, with more slender tips, these (seen from side) reach above the top of the last dorsal segment; from the side one sees a short median projection.

Length of fore wing: 14 to 16 mm.

Types numbered 28499 in the Museum of Comparative Zoology. Several specimens taken at light at Round Mt., Maine, by the Maine Forest Service, 15, 16, 17 July.

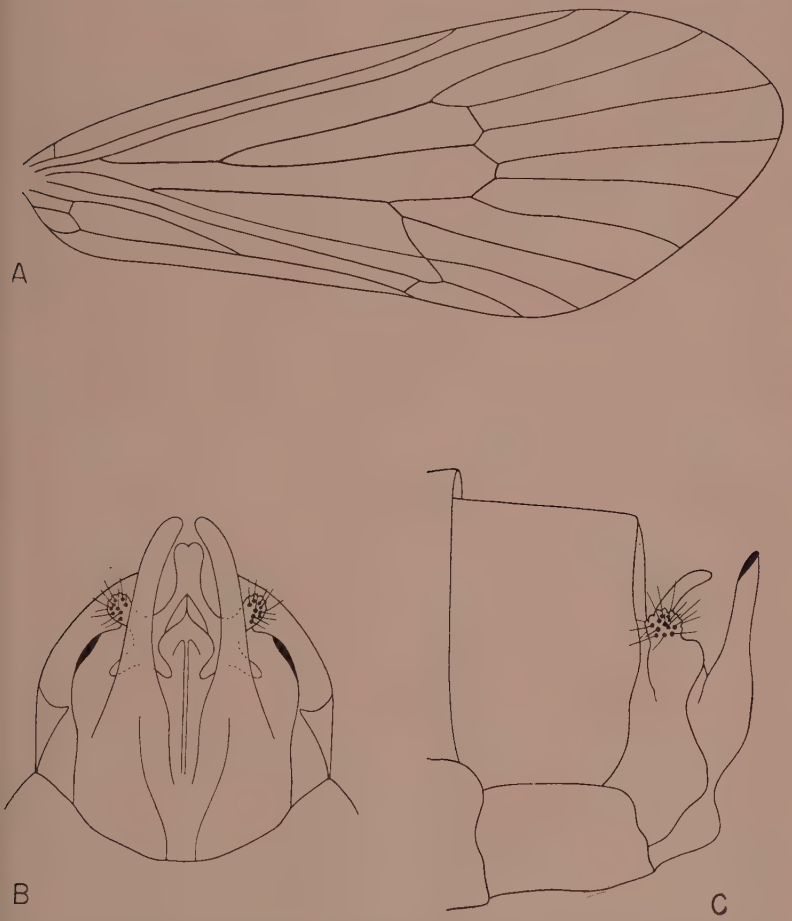

Figure 1. *Hydatophylax victor*, sp. nov. A, fore wing; B, posterior view, and C, lateral view, of end of abdomen of male.

LARGE RAPTORIAL BIRDS AS ENEMIES OF CICADAS

By Charles T. Brues

Harvard University

Cicadas form an important source of food for many carnivorous birds. There are abundant published records which attest the fondness of a great variety of birds for these large Homoptera which constitute a notable part of the insect fauna over many extensive areas throughout the world.

By reason of its periodical appearance in immense swarms, the North American *Magicicada septendecim* is naturally eaten in large numbers by a great variety of insectivorous birds on the rare occasions that it appears. Extensive records collated by Marlatt, Myers and McAttee[1] show that this cicada, as well as many others, frequently forms a part of the avian diet.

It is usually the smaller and less powerful species of birds which prey on cicadas, but often some of the larger raptorial Falconidae do not disdain to capture and eat them with apparent relish. An early account of kites feeding on cicadas in the American tropics is contained in Belt's "Naturalist in Nicaragua" published in 1874 (p. 230), where he found on dissection that their crops were filled with these insects. Later, in India, Distant, and also Bingham noted similar birds preying on cicadas and Myers (*loc. cit.*) quotes Australian records of similar occurrences.

During our recent stay in the Philippines we had the opportunity to observe the frequent capture of a very large cicada (*Cryptotympana acuta* Sign.) that was common during the summer months (May and June) in the wooded foot-hills above Dumaguete on Negros Island. I am indebted to my friend, Dr. Z. P. Metcalf for the specific determination. The cicadas could be seen frequently resting in numbers among the smaller branches of trees, and at frequent intervals one or several soaring kites would appear, circle among the high trees and pick off the immobile insects.[2] At this season the shrill din of the singing insects was very pronounced and

[1]Marlatt, C. L. The Periodical Cicada. Bull. U. S. Dept. Agric., n. s. No. 14 (1878). Myers, J. G. Insect Singers. G. Rutledge & Sons, London (1929). McAttee, W. L. Effectiveness in Nature of the So-called Adaptations of animals Chiefly as Illustrated by the Food Habits of Nearctic Birds. Smithsonian Misc. Coll., vol 85, No. 7 (1932).

[2]The identification of the birds is not positive, but they were, without much question, the common honey buzzard (*Pernis ptilorhynchus*).

the capture of one or two specimens was accomplished so adroitly that there was no interruption in the rhythm of the chorus. Occasionally a cicada would let out a piercing shriek as the bird's beak closed upon it, and instantly the whole assemblage lapsed into silence for a time while the kites drifted away. When picked up in the fingers the cicadas behave similarly with a sudden vocal outburst of unbelievable vigor, or if one is captured by a large mantis its prolonged swan-song assumes deafening proportions. Neither the mantises nor larger birds give any indication that they notice such outbursts, although they must have some protective value against smaller birds. In my own experience, the cicadas of more temperate regions do not respond so loudly to rough handling, particularly the periodical cicada which is very docile in this respect.

Although the actual capture of the cicadas by kites must depend upon sight, the preliminary approach of the birds to the trees is probably influenced by the shrill and incessant singing of the insects since the birds lose interest during temporary lulls in the chorus.

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